always an absorption band in the violet during the middle of a bright day in the mountainous regions. Its development is coincident with the gathering of a slight mist.

The illumination from an unclouded sky is about the same as from a completely clouded sky. The most light, however, comes from a sky which is partly covered with clouds. The so-called "cumulus" clouds produce especially good luminosity.

The isothermal layer of the atmosphere.—W. J. Humphreys, Mount Weather Meteorological Observatory.

The temperature of the atmosphere decreases more or less uniformly with increase in elevation above the surface of the earth until an elevation of from 30,000 to 60,000 feet is reached, where the temperature is $-50°$ to $-60°$ C. From this elevation up as far as balloons have gone the temperature remains practically constant. This is explained as the result of radiation, mainly from the moisture in the [lower atmospheric strata which has] an effective radiating surface of great extent in comparison with elevations reached by balloons.

The means of locating this surface was considered. The relative proportion of the different constituents of the air is different at different elevations, the proportion of water vapor being relatively great in the lower layers. Calculation shows the temperature of this "effective radiating surface" to be about $-33°$ C. (The calculations were carried through in detail before the joint session.)

This paper was afterwards (on August 27) read at the Put-in-Bay meeting of the Astronomical and Astrophysical Society of America, and again before the Philosophical Society of Washington, D. C. It will appear in full in the Astrophysical Journal for December, 1908. It is interesting to note that Professor Humphreys had anticipated by a few weeks only, the somewhat similar but wholly independent explanation offered for the same phenomenon by Mr. Gold at the Dublin meeting of the British Association on September 2, 1908.—*C. A. jr.*

THE ISOTHERMAL LAYER OF THE ATMOSPHERE.

[Reprinted from "Nature," London, of October 1, 1908, p. 550–2.]

The important discussion of which we give here a detailed account was organized by the committee of Section A of the British Association, and took place at the recent meeting at Dublin.

It was intended that M. Teisserenc de Bort should open the discussion, but he was unable to be present and sent the following communication:

Permit me to open the discussion on the isothermal layer and the inversions of temperature which are found there by recalling in a few words the results obtained during the past twelve years. Our experiments at Trappes have shown, in the first place, that the temperature ceased to diminish at a certain height after having passed thru a point of maximum rate of decrease about 3,000 meters lower down.

The altitude at which the diminution ceases changes with the character of the weather; it may descend as low as 8 kilometers at Paris during a cyclone, while it rises as high as 13 or 14 kilometers in high-pressure areas and in front of large cyclones.

I indicated these peculiarities for the first time in October, 1901, in a communication to the Luftschiffahrt Verein at Berlin, then in a communication to the Meteorological Society of France in March, 1902, and I developed these conclusions in a note to the Académie des Sciences in April, 1902.

A short time after, in the early part of May, 1902, Professor Assmann showed from the ascents of six rubber balloons that not only was there a cessation of the decrease in temperature, but also an inversion. This inversion had also been very marked in the first ascents by Hermite and Besançon, but Professor Assmann sought to explain it as being due to the effect of solar radiation on the thermometer while the ventilation produced by the rapid ascent of the balloon showed that it could not be referred to such an error in the thermometer record.

Having once demonstrated the existence of this isothermal layer for places in the neighborhood of Paris, we sought to find the evidence of it in other regions in order to show that it was a general phenomenon. Ascents made by us and our assistants in the winter of 1900–1, by M. de Quervain in Russia, by Mr. Eggeberger at Bath, England, in 1902, have made it evident that the phenomenon was a general one. On referring to the results of the international ascents made in different countries, it is seen that the cessation of the temperature decrease is found in the case of all the balloons sent up, and that it is impossible to refer it to insufficient ventilation, since the phenomenon was well marked in ascents made during the night. Since this time, ascents made on board the *Princesse Alice* by Professor Hergesell in 1905 have furnished evidence of the existence of the layer near the Azores; ascents made in the United States by Mr. A. L. Rotch have furnished evidence of its existence there with the peculiarities I have indicated, i. e., high up over high-pressure areas and low down over low-pressure areas.

The expeditions of the *Otaria*, organized in conjunction with my friend, Mr. Rotch, have proved the existence of the zone in the Tropics, and have shown it is further from the earth near the equatorial regions where the trade winds meet.

Finally, the ascents made at the end of the winters of 1907 and 1908 by the French-Swedish expedition organized by the Observatory of Trappes, with the support of Professor Hildebrandsson, have shown that near the Arctic Circle, at Kiruna, the layer exists and possesses general characteristics analogous with those found in these regions.

The results of series of daily ascents for eight, ten, or more days in succession in February, 1901. March, 1903, and May, 1904, have proved that the change of altitude of the point where the temperature ceases to fall is accompanied by changes of temperature of 10° C., 15° C., 20° C., in an interval of a day or two at heights between 9 and 13 kilometers, variations great enough to be felt near the surface during the same time.

Thus the equalization of temperature in the course of the year which had been supposed to be nearly complete at 8 or 9 kilometers altitude does not exist, but, on the contrary, sudden changes of temperature occur with the passage of cyclones and anticyclones which would furnish to an observer in those regions the chief evidence of the changes occurring at the surface.

Causes of the isothermal layer.—The summary of the observed phenomena has led me to this conclusion, that the cessation of the temperature diminution is due to the fact that there is at these heights no considerable vertical convection.

The fact that one meets with layers of air thousands of meters thick where the temperature increases and decreases rapidly, and others where it is stationary, is incompatible with the existence of motion of the air accompanied by pressure variations, which always tend to produce a vertical temperature gradient more or less near that for the adiabatic state. It does not follow that the movement in the isothermal layer must be horizontal, but that it takes place along the isobars without crossing these surfaces nearly in the manner in which a body rolls on an inclined plane.

These ideas have been developed in several communications, in particular at the Conférence d'Aérostation scientifique at St. Petersburg in September, 1904.

In the absence of M. L. Teisserence de Bort, Doctor Shaw opened the discussion. He explained what was the main feature of the phenomenon, and showed how it had been corroborated by *ballon sonde* ascents made in England. The temperature of the air decreases in the lower layers on the average at 5° or 6° C. per kilometer up to a height of about 10 kilometers. Above this height the temperature ceases to fall rapidly and falls very slowly indeed, or remains constant, or in some cases increases. It has been suggested that the phenomenon might be due to a change in the composition of the air at great heights. M. L. Teisserenc de Bort had succeeded in sending up balloons carrying vacuum tubes which were opened and resealed electrically at a height of 14 kilometers. The samples of air so obtained were examined spectroscopically, and the examination showed that there was no change in the composition of the air sufficient to account for the cessation of temperature diminution.

Remarks by A. L. Rotch.

Mr. Rotch said that the only *ballons sondes* which have been sent up in America were those dispatched by him. Since 1904 76 rubber balloons have been launched from St. Louis and all but one have been recovered. The majority of those which rose higher than 12,870 meters (8 miles) entered the stratum of relatively high temperature.

All the ascents occurred after sunset, so that there can be no question as to the effect of solar radiation. The instruments used were of M. Teisserenc de Bort's construction, and were verified for low pressures and temperatures before and after the ascents. The warm stratum, which was not isothermal but became warmer with increased height, was at its lowest level in summer, having a minimum temperature of $-54.6°$ C. at 12,000 meters. During the autumn of 1907 the stratum of warm temperature was penetrated eight times, the mean minimum temperature of $-60.5°$ occurring at 12,370 meters.

The changes in the level of the minimum temperature from day to day were large. Thus the minimum of −67.1° C. at a height of 14,500 meters on October 8 was followed two days later by a descent of the minimum of −62.2° C. to 12,000 meters. In the first case the temperature at the highest point reached, viz, 16,500 meters, was −58.1° C., and in the second case, when 15,000 meters was attained, −56.0° C. On November 6 the minimum temperature of −52.2° C. occurred at 9,700 meters, but the place of occurrence of the minimum of −63.1° C. had risen to 14,250 meters on November 8. The temperatures at the highest points reached were −50.5° C. at 10,000 meters and −60.2° C. at 15,380 meters, respectively.

These observations, made near latitude 35° north, show the warm stratum to be at a distinctly higher level than in northern Europe, whereas the results obtained by the expedition sent jointly by M. Teisserenc de Bort and the speaker to explore the atmosphere over the tropical Atlantic in 1906–7 show that it was there considerably higher. In fact, the observations obtained over the equator up to 15,000 meters show no reversal of temperature, and a lower temperature than exists at a corresponding height in northern latitudes.

Remarks by Mr. Cave.

Mr. Cave said that during the last week in July he was able, by means of theodolites, to follow four balloons into the isothermal layer. From these observations it appeared that the wind velocity increased to a maximum just below the isothermal zone, and decreased rapidly above. The wind velocities were very high, and most of the balloons went out to sea; one, sent up on July 28, was recovered. From the record of the meteorograph it appears that the isothermal layer was entered at 11,500 meters; the theodolite observations indicated that this was the height of the maximum wind velocity; above this the velocity dropt to eight miles per hour at 13,000 meters.

Remarks by W. H. Dines.

Mr. W. H. Dines said that he knew there had been some doubt exprest about the existence of the isothermal layer, and possibly there were still some who thought that the results obtained were due to instrumental errors. Such a view was now quite untenable, for about 70 ascents had been made in the British Isles during the last eighteen months, and the results entirely confirmed those previously made on the Continent and in America, altho the instruments used for recording the temperature were of totally different patterns. These ascents had mostly been made about the time of sunset so that no possibility of solar influence might be present, but in every one of the 60 cases, when a sufficient height had been reached, the temperature gradient became negligible or of opposite sign. After calibrating many instruments he was convinced that the temperatures recorded were, with but few exceptions, correct within 2° or 3° C.

The results, however, were most remarkable, and it was not surprising that their accuracy had been doubted. It had been found that over places only a few hundred miles apart, and at the same time, the temperatures might be widely different, and within the same week and over the comparatively small area of the British Isles differences of 30° C., had been recorded, namely, −40° C. at 15,000 meters at Limerick on July 27; −60° C. at Pyrton Hill, Oxon., on the same date; and −69° C. at Pyrton Hill on July 29, and again on July 30. Very similar differences between Manchester, Ditcham Park, and Pyrton Hill had been noted on previous occasions.

The absence of any temperature gradient in the air is definite proof of the absence of any vertical circulation, but this alone did not present any difficulty. He had always thought that the vertical circulation was chiefly due to the heat set free when aqueous vapor was condensed to water, and since it was known that the relative humidity was small at great heights, it might well be that above 10 or 12 kilometers there was no aqueous vapor, and therefore no vertical circulation, The difficulty was how large temperature differences could exist at small distances apart without producing convection currents. In a mass of gas at rest under a conservative system of forces the isobaric or isothermal surfaces must be coincident. In this case the temperature observations led to two contradictory results—they showed that there was no circulation and also that the isobaric and isothermal surfaces were not identical. At a height of 15 kilometers a very small change of pressure would produce a large adiabatic change of temperature, but it was difficult to see how with so small a mass of air left above, changes of pressure could be produced. The accelerations produced by curvilinear motion of the air particles, and by the effect of the earth's rotation on a moving body appeared to be far too small for the purpose. Was it possible that the upper air could carry a sufficiently strong electric current to be influenced by the earth's magnetic field, and so produce forces comparable with gravity? Professor Schuster had suggested some such origin for the daily variation of the magnetic declination.

Remarks by Mr. Gold.

Mr. Gold said that any explanation of the existence of the isothermal layer must take into consideration the effect of atmospheric radiation. On the assumption that the radiation per unit area from a layer of gas was proportional to the mass of gas in the layer, and that the absorption followed the same law, he had worked out some results for the earth's atmosphere. If the atmosphere were of uniform constitution, so that the absorption by a layer of air of given mass was the same at whatever height the layer was taken, then the state of convective equilibrium could not exist to heights greater than those corresponding to a pressure equal to half the surface pressure. He found that for greater heights than this the radiation absorbed from the earth and the rest of the atmosphere alone was greater than that emitted at a temperature corresponding to the state of convective equilibrium. In consequence of this the temperature of the air in the upper layers would rise, and there would be a further increase owing to the absorbed solar radiation. In the actual case, the absorbing power of the atmosphere diminishes with increasing height owing to the diminution in the proportional amount of water vapor present. The absorbing power was therefore taken to be $a \div (q-p)$, where a and q are constants. Two values were taken for q, for one of which the diminution in absorbing power was quicker, in the other slower than the diminution in the proportion of water vapor present. The value of a was deduced from the observations of Langley, Paschen, and others.

The conclusions arrived at were:

(1) If the temperature gradient in the lower layers of the atmosphere is such that T varies as $p^{1/4}$, i. e., is approximately adiabatic, and if the upper layer is isothermal, then the state $T \propto p^{1/4}$ must extend to a height greater than that for which $p=p_0 \div 2$, and in general less than that for which $p=p_0 \div 4$, where p_0 is the surface pressure.

(2) The temperature in the lower layers cannot be maintained by absorption of terrestrial and solar radiation; these layers tend to grow cooler, and their temperature is kept up by the supply of heat thru convection from the earth's surface and by condensation of water vapor in the atmosphere.

(3) The lowest possible temperature in the atmosphere over a place at temperature 300° A. (absolute), must be greater than 150° A., or 210° A., according as the atmosphere radiates and absorbs thruout the spectrum or transmits freely 25 per cent of the earth's radiation.

Remarks by Professor Turner.

Professor Turner said that whereas meteorologists were, perhaps, primarily concerned with the facts themselves, and physicists with the causes of them, astronomers were interested in the effects of the existence of this isothermal layer, especially in the phenomena of atmospheric refraction. It had been usual to make certain assumptions about the upper air for the calculation of refraction, and these assumptions were now shown to be wrong. Were the refractions calculated on such assumptions wrong? The answer seemed to be that very rough assumptions were sufficient for astronomers; he had found, for instance, that the assumption of two homogeneous shells of air would give empirical results corresponding closely to the facts observed.

Further, no very great improvement was found by adding a third shell—the chief step came in taking two instead of one. Possibly this fact, that two shells were absolutely necessary, but a third was not so much needed, was in some way connected with the existence of two principal regions in the atmosphere.

Prof. J. J. Thomson asked if there was any indication of the thickness of the layer, and remarked that the ionisation in the atmosphere was a maximum at a layer considerably below this layer.

Doctor [Gilbert T.] Walker stated that the Indian peasants were so ignorant that he had not yet ventured on sending up *ballons sondes* there, the chances of recovering them being so remote.

DAMAGES BY FLOOD AT KANSAS CITY, MO.

Thru an oversight, the statistics regarding flood damage at Kansas City, Mo., were unduly abbreviated in the MONTHLY WEATHER REVIEW for July, 1908. The paragraph on p. 206 relating thereto should read as follows:

> The damage at Kansas City was very small compared with that caused by the flood of 1903, in fact, the damage to property was very light considering the size of the flood. Twenty-three business institutions in the bottoms, some in Kansas City, Mo., and some in Kansas City, Kans., report a total damage to property of only $91,500. The same number report a total loss by enforced suspension of business of $168,000 and value of property saved by the flood warnings of the Weather Bureau of $1,324,000. These figures multiplied by 10 will, in each case, fairly represent results, making a grand total of damage to property of $915,000 and loss to business of $1,684,000. The value of the Weather Bureau warnings is conservatively estimated at $5,000,000. The railroad losses were only about $350,000.

With this alteration the total losses in the Missouri Valley from Plattsmouth, Nebr., to Boonville, Mo., amount to $10,919,000.—*C. A., jr.*

THE SCIENTIFIC ASPECT OF A BALLOON VOYAGE.

By H. H. CLAYTON. Dated Bluehill, Mass., September, 1908.

[Reprinted in part from the Boston Sunday Herald, August 9, 1908.]

The trip described below was made from North Adams, Mass, on July 29, in company with Mr. Charles J. Glidden, of Boston.

The morning of July 29 seemed very unfavorable for an ascent at North Adams, Mass., since the sky was covered with a very low sheet of cloud which seemed to threaten rain. By 10 o'clock this stratum of cloud had cleared away. The sun came out, brilliantly hot, causing a rapid rise in temperature. While we were discussing the arrangements for the voyage and the time of leaving, we noticed that clouds such as are usually associated with thunder-storms had already begun to form over the mountains, and it seemed wise to postpone the beginning of the voyage until the late afternoon, a time which Mr. Glidden had previously found to be especially favorable for balloon voyages.

By 1 o'clock the clouds had developed enormous proportions over the Hoosac Mountains, and showed the overspreading tops characteristic of local thunder-storms. Under these conditions it seemed unsafe for a balloon, and the voyage was postponed until the clouds had begun to show signs of disappearing. Finally, at 4:30 p. m., the ascent was begun.

The wind was at the time very light, but showed a prevailing direction from slightly south of west. As the balloon rose it moved with increasing speed directly eastward toward the Hoosac Mountains. After we had risen to a height of about 2,000 feet we were traveling eastward at a speed of about 6 miles an hour.

THE UPDRAFT.

The temperature at the ground when we left was 86° and already it had fallen about 10°. As we approached the mountain, the balloon steadily rose to a greater height, indicating a strong ascent of air over the peak, where clouds still were seen but of much less proportions than in the earlier afternoon.

As the balloon came near the summit of the mountain it was caught in the whirling vapor and carried upward to a height of about a mile, the ascent being aided, however, by the throwing out of ballast in hopes that we might rise above the top of the cloud. As we approached the cloud the shadow of the balloon was seen distinctly outlined on the ragged mass of vapor, surrounded by rings of colored light.

The updraft over the mountain is indicated in outline in figure 1. This shows the clouds formed in this ascending current, and the balloon at the point of entering the upper portion of the cloud. The observations in the balloon showed that the temperature at this point had fallen to 68°; the clouds were formed by the chilling of the air due to its own expansion and the condensation of the invisible moisture which it contained.

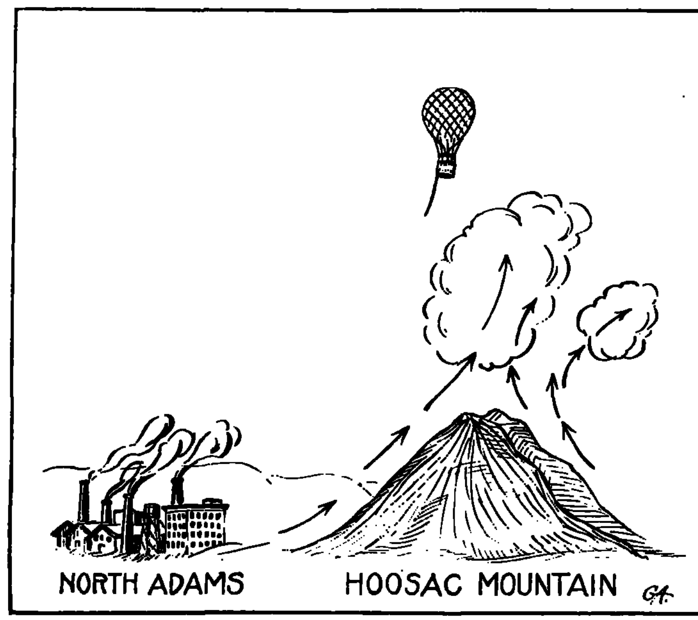

FIG. 1.—The updraft over Hoosac Mountain on July 29, 1908.

As the balloon passed the mountain summit and lost the ascending current which sustained it it began to descend rapidly, because in rising into the thinner air it had lost a part of its gas, which had flowed out at the bottom of the bag. Hence, the bag being unable to support its previous load, it was necessary to throw out sand very quickly to prevent falling entirely to the ground.

Notwithstanding, we fell so rapidly that the sand was past, the balloon dropping faster than the finest grains of sand. The rate of descent was about 6,000 feet a minute. This continued until the trail ropes touched the tops of the trees, after which the balloon, being relieved of part of its weight, floated smoothly along.

THE PATH OF THE BALLOON.

The path of the balloon from North Adams to its place of landing is shown by the broken line, figure 2. An analysis of this course shows that its bend was due to an indraft of air